Eur J Vasc Endovasc Surg **20**, 84–89 (2000)
doi:10.1053/ejvs.2000.1102, available online at http://www.idealibrary.com on IDEAL®

Perioperative Factors Influencing the Outcome of Elective Abdominal Aorta Aneurysm Repair

J. P. Becquemin*[1], E. Chemla[2], G. Chatellier[2], E. Allaire[1], D. Mellière[1] and P. Desgranges[1]

[1]*Hôpital Henri Mondor, AP/HP Paris, University Paris XII, Créteil, 94000, France;* [2]*Hôpital Broussais, AP/HP Paris France, University Paris VI, Paris, 75006, France*

Purpose: *to identify perioperative variables which may influence mortality of elective abdominal aneurysm repair (AAA).*
Method: *prospective study of patients undergoing elective AAA repair between 1986 and 1997.*
Results: *four hundred and seventy patients (438 men, 32 females) with a mean age of 69.4 ± 13 years and aneurysms with a diameter of 60 ± 3 mm were operated on with a 1-month mortality rate of 5.3%. Multivariate analysis identified the following independent risk factors for mortality: age >70 (p<0.0001), a past history of myocardial infarction (p<0.0001), preoperative renal insufficiency (p<0.0001), reoperation (p<0.0001), colonic necrosis (p<0.0001), and severe postoperative medical complications (p<0.0001).*
Conclusion: *intra- and postoperative events affect the outcome of AAA repair, independently of preoperative factors, and should be described when presenting the results of AAA repair.*

Key Words: Abdominal aortic aneurysms; Factors of early mortality; Surgery.

Introduction

The frequency of aneurysms of the abdominal aorta (AAA) has increased with an estimated 5% current prevalence in the population aged over 65.[1] In the same time, the mortality of open elective surgery of AAA has steadily been reduced since the publication by Dubost *et al.* in 1951,[2] with rates from approximately 20% 40 years ago to 4%–5% nowadays.[3,4] This improvement is probably due to better patient selection, technical refinements in surgery and anaesthesia, and better postoperative management.

There is a general consensus that aneurysms over 5.5 cm in diameter should be treated surgically and those below 4 cm should be monitored, while for aneurysms of intermediate size the decision should be made case by case.[5] The UK Small Aneurysm Trial showed that ultrasonographic surveillance for small aneurysm (4.0–5.5 cm) is safe and that early surgery does not provide a long-term survival advantage.[6] This conclusion was based on a relatively high postoperative mortality rate of 5.6%.

Previous studies have attempted to identify factors which may predict adverse outcome after surgery. Attention has mainly been focused on preoperative risk factors where it has been shown that age, renal insufficiency and coronary heart disease were independent markers for postoperative mortality.[7–9] Few studies have taken into account intraoperative factors such as diameter of the aneurysm, duration of surgery, blood loss[10,11] or postoperative events such as reoperations and occurrence of vascular or general complications[3,12,13] which may have a significant impact on mortality figures.

The aim of this prospective study was to identify pre-, intra- and postoperative factors for mortality, in a consecutive series of 470 patients who underwent open elective surgery for AAA in a single centre over a period of 12 years.

Patients and Methods

Since 1985, a specifically developed software program has been used to prospectively document all patients admitted in the Vascular Surgery department of Henri-Mondor Hospital, Creteil, France. Patients who were operated on electively for infra- or juxtarenal aneurysm of the abdominal aorta (AAA) between January 1986 to December 1997 have been studied.

Indications for surgery were a diameter of at least

* Please address all correspondence to: J. P. Becquemin, Department of Vascular Surgery, Hôpital Henri Mondor, AP/HP Paris, University Paris XII, Créteil, 94000, France.

1078–5884/00/070084 + 06 $35.00/0

5 cm, or rapid growth as on 6-monthly duplex scans. Patients with a short life expectancy due to advanced age, definite incapacity with nursing dependance, incurable neoplasm, incorrectable severe heart disease or end-stage renal insufficiency were denied surgery.

The aneurysm was assessed in most cases by CT scan and aortograms. Preoperative work-up comprised surgical and anaesthetic consultations. All patients had ECG and biochemistry investigations including WBC and platelet counts and prothrombin time. Except for very large aneurysms, patients with a past history of myocardial infarction or angina pectoris were screened by a thallium dobutamine scintigraphy and/or cardiac ultrasound study with exercise test. Coronary angiography was performed selectively, according to the results of the non-invasive studies, or as the investigation of choice in patients with unstable angina pectoris. Whenever necessary and feasible, angioplasty or coronary bypass surgery was performed before surgery of the abdominal aorta. Four weeks of chest physiotherapy was performed in patients with chronic obstructive pulmonary disease. Patients with a carotid stenosis greater than 80% on duplex ultrasound underwent carotid surgery prior to AAA repair.

A median laparotomy was used except in obese patients, where a transverse laparotomy was performed. For aneurysms requiring a suprarenal clamp, a retroperitoneal approach was adopted.

Before clamping, unpurified heparin was administered intravenously at 0.5 mg per kg. This continued throughout the stay in hospital with the aim of achieving a kaolin-activated prothrombin time of 1.5 times the control value.

Definitions of variables

Preoperative factors

Risk factors were graded and recorded according to the recommendations of the SVS/ISCVS.[13] However, on the account of the limited number of patients in each category, and in order to obtain adequate statistical power, grades were pooled as follows.

Cardiac function. No or minor coronary disease included asymptomatic patients, normal ECG, myocardial infarction more than 6 months previously or silent infarction diagnosed by ECG. Significant or severe coronary disease included stable angina pectoris, asymptomatic arrhythmia, left-ventricular failure compensated by medical treatment, unstable angina pectoris, chronic atrial fibrillation, uncompensated left-ventricular failure, previous myocardial infarction in the 6 months preceding surgery. We also tested separately previous myocardial infarction, chronic atrial fibrillation, and left-ventricular dysfunction.

Renal function. No or minor renal dysfunction included no alteration of renal function, serum creatinine below 110 μmol/l or serum creatinine between 110 and 200 μmol/l. Moderate or severe renal dysfunction included serum creatinine between 200 and 400 μmol/l, serum creatinine above 400 μmol/l and patients undergoing dialysis or with renal transplant.

Respiratory function. Normal pulmonary function included asymptomatic patients with normal chest X-ray. Abdominal pulmonary function included the remaining respiratory function grades of the SVS/ISCVS classification: 1 = patient asymptomatic or with slight exercise dyspnoea, defects of the parenchyma visible on chest X-ray; 2 = between 1 and 3; 3 = vital capacity less than 1.85 l, FEV_1 less than 1.2 l/s or less than 35% of expected FEV_1, maximum breathing capacity less than 28 l/min or less than 50% of the expected value, pCO_2 greater than 45 mmHg, oxygen therapy required or high pulmonary artery blood pressure. Obesity included excess weight greater than 20% of theoretical weight. Obesity was defined as body weight >120% of ideal.

Intraoperative factors

Type of abdominal incision, the need for a groin incision, the presence of expected or unexpected non-vascular intra-abdominal pathology (gallstones, cancer, diverticulitis), the level of aorta cross-clamping, the use of a tube or a bifurcated graft, the revascularisation of renal, inferior mesenteric, or hypogastric arteries, the duration of operation, and the volume of blood loss.

Postoperative factors

Need for reoperation within one month or during the hospitalisation, and the occurrence of vascular, non-vascular, and remote or general complications graded as severe or fatal in the SVS/ISCVS classification.

Endpoint

Endpoint was postoperative mortality defined as death before discharge from hospital or occurring within 30 days of the operation.

Statistical analysis

All variables defined above were submitted to a univariate analysis to test their influence on the endpoint. Student's *t*-test, χ^2 test or Fisher's exact test were calculated using Statview statistical software (Abacus,

Table 1. Baseline characteristics of the population.

Population		Alive	Deceased
	Number (%)	Number (%)	Number (%)
Age >70 years	196 (42)	175 (89)	21 (11)
Age <70 years	274 (58)	270 (98.5)	4 (1.5)
CAD	128 (27)	117 (91.5)	11 (8.5)
No or minor CAD	342 (63)	327 (95.5)	14 (4.5)
Previous MI	129 (27)	116 (90)	13 (10)
No MI	341 (63)	329 (96.5)	12 (3.5)
LV dysfunction	166 (35)	156 (94)	10 (6)
Normal LV function	304 (65)	289 (95)	15 (5)
Pulmonary disease	50 (10.6)	43 (90)	5 (10)
No pulmonary disease	420 (89.4)	402 (95)	20 (5)
Severe renal dysfunction	15 (3)	9 (60)	6 (40)
Normal or mild dysfunction	455 (97)	436 (96)	19 (4)
Obesity	52 (11)	51 (98)	1 (2)
Normal weight	418 (89)	394 (94)	24 (6)
Arrhythmia	31 (6.5)	30 (97)	1 (3)
Normal rhythm	439 (93.5)	414 (94)	25 (6)
OSFA	89 (19)	83 (93)	6 (7)
No OSFA	381 (81)	362 (95)	19 (5)

LV: left ventricle; OSFA: occlusive disease of the superficial femoral artery.

CA, U.S.A.). Variables which were statistically significant, with p-values <0.05, were entered into a maximum probability logistic regression program (SAS System, Los Angeles, CA, U.S.A.). For each significant variable in the multivariate analysis, odds ratios (OR) were calculated with a 95% confidence interval.

Results

The characteristics of the patient population ($n=470$) are presented in Table 1. There were 32 females and 438 men with an average age of 69.4 ± 13. A midline or transverse laparotomy was performed in 366 cases (78%) and a retroperitoneal approach in 108 cases (22%). The aorta was clamped below the renal arteries in 390 cases (83%) and above the renal in 80 cases (17%). There were 157 bifurcated (33%) and 313 tube grafts (67%). Twenty-five patients died postoperatively (5.3%) (Table 2). Thirty-eight patients (8%) required reoperation; 11 of them died (29%) (Table 3). Univariate analysis showed that the following factors were significantly associated with a higher mortality:

Preoperative factors: average age, 72.5 years old and 66.2 years old respectively for deceased and surviving patients ($p<0.0001$); moderate or severe renal dysfunction (24% vs. 2%, $p<0.001$); previous myocardial infarction (52% vs. 18%, $p<0.01$); aneurysm diameter (60.8 mm vs. 51.2 mm, $p<0.01$); presence of internal iliac aneurysms (24% vs. 9.4%, $p<0.05$).

Table 2. Distribution of the most severe postoperative events which ultimately led to death in 25 patients.

Adverse post-op. events	Number	(%)
Reoperation	11	(44)
Cardiac complication	6	(24)
Pulmonary complication	3	(12)
Colonic necrosis	3	(12)
Septicaemia	1	(4)
Acute pancreatitis	1	(4)
Total	25	(100)

Table 3. Distribution of reoperations and outcome in a series of 470 patients with non-urgent AAA treated by open repair.

Causes	Alive		Dead	
	Number	(%)	Number	(%)
Ischaemic complications*	9	(33)	7	(64)
Haemorrhage	7	(26)	4	(36)
Evisceration	5	(18)	0	(0)
Graft infection	2	(7)	0	(0)
Groin haematoma	1	(4)	0	(0)
Groin infection	1	(4)	0	(0)
Intestinal infection	1	(4)	0	(0)
Ruptured spleen	1	(4)	0	(0)
Total	27	(100)	11	(100)

* Include lower limb ischaemia in three patients and colonic ischaemia in six.

Intraoperative factors: associated intra-abdominal pathology (39% vs. 17%, $p<0.05$); blood loss (1.9 l vs. 1.1 l, $p<0.05$).

Postoperative factors: reoperation (44% vs. 6%, $p<0.0001$); colonic necrosis (12% vs. 1%, $p<0.0001$); severe medical complications (52% vs. 8.5%, $p<0.01$) (Table 4).

None of the remaining tested variables were found to be significantly associated with death in this series.

The multivariate analysis showed that only six of these factors were independent variables: renal dysfunction ($p<0.0002$; OR = 40), colonic necrosis ($p<0.002$; OR = 22), severe medical complications ($p<0.0001$; OR = 20), reoperation ($p<0.0001$; OR = 18), age ($p<0.001$; OR = 15), and previous myocardial infarction ($p<0.002$; OR = 6).

Table 4. Distribution of medical complications which occurred after AAA repair.

Complications	Number	(%)
Myocardial ischaemia	8	(15)
ARF	6	(11)
Pneumopathy	5	(10)
MI	4	(8)
RPH	4	(8)
Lower-limb phlebitis	4	(8)
Groin haematoma	4	(8)
Septicaemia	3	(6)
Urological complications	3	(6)
Diverticular sigmoiditis	3	(6)
Multi-organ failure	2	(4)
Acute pancreatitis	1	(2)
Paraplegia	1	(2)
Stroke	1	(2)
Ascitic infection	1	(2)
Allergy to heparin	1	(2)
Total	51	(100)

ARF: acute renal failure; MI: myocardial infarction; RPH: retroperitoneal haematoma.

Discussion

The postoperative mortality rate of 5.3% is similar to that reported in the literature, where figures range from 0 to 10.5%.[15] Mortality figures depend upon the date of observation and the type of report (retrospective vs. prospective, controlled vs. uncontrolled, single centre vs. multicentre). In selected series from high-volume centres, mortality rate may be as low as 1.7%;[10] but this figure probably does not reflect the true mortality of AAA repair in most places. Katz *et al.*,[16] in a collective series of 8185 patients undergoing elective surgery for AAA between 1980 and 1990, reported an overall mortality rate of 7.5%.[16] Interestingly, mortality varied with time. The mortality rate was 13.6% in 1980 and 5.6% in 1990, despite the fact that patients in the latter period were older and had more risk factors. Katz *et al.* suggested that it may be due to better perioperative management, but also to the pernicious effects of the coding systems which underlie budgetary allocations to hospital departments.[16] Large multicentre trials involving selected high-volume centres reported lower mortality rates than national registers.[8,11,17–20] In a previous report collecting studies published between 1985 and 1997,[15] we found a 5.8% mortality rate for a total number of 35 569 patients. Large multicentre studies reported a figure of 4.1% for 11 072 patients, studies carried out in large centres presented a mortality of 3.1% for 6619 patients, and national registers a mortality of 7.8% for 17 878 patients. It therefore seems legitimate to estimate the mortality rate for elective surgery of AAA around 5%. This figure is supported by the UK Small Aneurysms Trial, where the mortality rate was 5.6%.[6]

Our series is a single-centre university hospital study. Even though there were several surgeons, including two senior surgeons and eight trainees, and different anaesthetists, the selection and management of patients were broadly similar over the period of observation.

Identifying factors predictive of postoperative mortality is of paramount importance in patient selection. However, intra- and postoperative events are unpredictable and may not always be patient-related.

Preoperative factors

As in previous studies, age, severe renal dysfunction and previous myocardial infarction were found to be strong independent predictors of postoperative death.[7–9,15,21,23] However, we were unable to find any influence of mild to severe coronary disease, as well as arrhythmia and left-ventricular dysfunction. This may be due to the relatively small number of events and the need for pooling different grades of cardiac severity. Furthermore, our coronary heart-diseased patients have been screened and treated before the AAA repair.

A meta-analysis was carried out by Steyerberg of well-documented series and of a series of patients operated on in Leiden. He reported on 17 238 patients with an overall mortality of 6.8%. Mortality was significantly increased in the presence of renal insufficiency, heart failure, symptomatic angina pectoris, respiratory insufficiency and age (in decade groups).[22] This report, like that of the SVS-ISCVS joint council in 1992, proposed scores that enabled the probability of death after AAA repair to be established. Interestingly, Steyerberg's score takes into account the current mortality rate of each individual centre to determine the probability of postoperative death for a given patient in a given centre.

The influence of aneurysm morphology on postoperative mortality is controversial. One might have expected that the more complex the anatomy, the poorer the outcome, but this is not a universal finding.[11,26] In the current study, aneurysm diameter was not an independent predictor of mortality, nor was suprarenal clamping, common iliac or external iliac extension or associated revascularisation of renal nor inferior mesenteric artery. The only anatomical feature which was predictive of higher mortality was the presence of internal iliac aneurysms. These findings are in agreement with two previous studies which respectively showed a 5.2-fold[27] and 20-fold[28] increase in the mortality rate when one or two hypogastric

aneurysms were present. Although the multivariate analysis showed that this was not an independent factor, we strongly believe that hypogastric aneurysms remain a major technical problem.

Intraoperative factors

Intraoperative events are rarely mentioned as predictors of mortality, possibly because surgeons are reluctant or unable to objectively assess their own performance. Although not independent, two factors were found to significantly increase the mortality in the univariate analysis: blood loss and associated intra-abdominal pathology.[11,24,25] Reducing blood loss is an important goal for the surgeon, more important than performing a rapid operation.

Postoperative factors

Reoperation was the most frequent complication in the group of patients. Although reoperation itself was rarely the final and sole cause of death, it did trigger a cascade of complications, including infection, myocardial infarction and multiple organ failure. If the role of reoperation is skimmed over, the weight of postoperative medical complications may be extremely overestimated. Amundsen already stressed the importance of reoperation as a factor leading to increased mortality.[11] Milne showed that reoperation for haemorrhage leads to death in 30% of cases.[12] More than 33% of patients undergoing surgery for AAA suffer from various adverse postoperative events,[9] but among them reoperation deserves special attention. Reoperation for haemorrhage is often complicated by coagulation disorders, which increase the postoperative mortality by 7.9-fold,[12] by haemodynamic instability which increases the risk of cardiac complication, and by transfusion which increases the risk of pulmonary complication. Finally, all postoperative complications increase the length of stay in the intensive care unit, which increases the risk of nosocomial infection. There is an obvious relationship between the postoperative surgical complications and intraoperative management. It remains to be determined, however, whether changes in technique could alter the prevalence and consequences of these complications.

Acknowledgement

The statistical analysis was made by G. Chatelier from the Department of Statistics of Broussais Hospital, France.

References

1 The UK Small Aneurysm Trial: design, methods and progress. *Eur J Vasc Endovasc Surg* 1995; **9**: 42–48.
2 Dubost C, Allary M, Oeconomos N. Resection of an aneurysm of the abdominal aorta: reestablishment of the continuity by a preserved arterial graft, with result after five months. *Arch Surg* 1952; **64**: 405–408.
3 Chen J, Hildebrand H, Salvian A *et al.* Predictors of death in nonruptured and ruptured abdominal aortic aneurysms. *J Vasc Surg* 1996; **24**: 614–623.
4 Zarins C, Jr EH. Operative repair for aortic aneurysm: the gold standard. *J Endovasc Surg* 1997; **4**: 232–241.
5 Brown P, Pattenden R, Vernooy C, Zelt D, Gutellius J. Selective management of abdominal aortic aneurysms in a prospective measurement programme. *J Vasc Surg* 1996; **23**: 213–222.
6 The UK Small Aneurysm Trial Participant Mortality results for randomized controlled trial of early elective surgery or ultrasonographic surveillance for small abdominal aortic aneurysms. *Lancet* 1998; **352**: 1649–1655.
7 Branchereau A, Nazet J, Colavolpe J, Scotti L. Mortalité-morbidité de la cure chirurgicale directe des anévrismes de l'aorte abdominale. *Ann Chir Vasc* 1990; **4**: 10–14.
8 Hollier L, Taylor L, Ochsner J. Recommended indication for operative treatment of abdominal aortic aneurysms. Report of a subcommittee of the joint council of the society for vascular surgery and the North American chapter of the international society for cardiovascular surgery. *J Vasc Surg* 1992; **15**: 1046–1056.
9 Johnston K. Multicenter prospective study of nonruptured abdominal aortic aneurysm. Part II. Variables predicting morbidity and mortality. *J Vasc Surg* 1989; **9**: 437–447.
10 Calligaro K, Azurin D, Dougherty M *et al.* Pulmonary risk factors of elective abdominal aortic surgery. *J Vasc Surg* 1993; **18**: 914–921.
11 Amundsen S, Skaerven R, Trippestad A, Soreide O and members of the Norwegian aortic aneurysm trial. Abdominal aortic aneurysm. A study of factors influencing postoperative mortality. *Eur J Vasc Surg* 1989; **3**: 405–409.
12 Milne A, Murphy W, Bradbury A, Ruckley C. Postoperative haemorrhage following aortic aneurysm repair. *Eur J Vasc Surg* 1994; **8**: 622–626.
13 Savers R, Thompson M, Nasim A *et al.* Surgical management of 671 aortic aneurysms. A 13 year review from a single center. *Eur J Vasc Endovasc Surg* 1997; **13**: 322–327.
14 Rutherford R, Flanigan D, Gupta S *et al.* Suggested standards for reports dealing with lower extremity ischemia. *J Vasc Surg* 1986; **4**: 80–94.
15 Becquemin JP, Chemla E, Allaire E, Desgranges P, Mellière D. Anévrismes de l'aorte abdominale. Résultats du traitement chirurgical moderne à froid. *J Cardiovasc Surg* 1998; **39** (Suppl. 1 to no. 1): 15–21.
16 Katz D, Stanley J, Zelenock G. Operative mortality rates for intact and ruptured abdominal aortic aneurysms in Michigan: an eleven year statewide experience. *J Vasc Surg* 1994; **19**: 804–817.
17 Samy A, Whyte B, McBain G. Abdominal aortic aneurysm in Scotland. *Br J Surg* 1994; **81**: 1104–1106.
18 Wen S, Simunovic M, Williams J *et al.* Hospital volume, calendar age, and short term outcomes in patients undergoing repair of abdominal aortic aneurysms. The Ontario experience, 1988–92. *J Epidemiol Community Health* 1996; **50**: 207–213.
19 Kazmer A, Jacobs L, Perkins A *et al.* Abdominal aortic aneurysms repair in Veterans affairs medical center. *J Vasc Surg* 1996; **23**: 191–200.
20 Hannan E, Kilburn H, O'Donnel J. A longitudinal analysis of the relationship between in-hospital mortality in New York state and the volume of abdominal aortic surgeries performed. *Health Serv Res* 1992; **27**: 517–542.
21 D'Angelo F, Vaghi M, Zorzoli C, Gatti S, Tacconi A. Is age an important risk factor for the outcome of elective abdominal aortic surgery? *J Cardiovasc Surg* 1993; **34**: 153–155.

22 Steyerberg E, Kievit J, de Mol Van Oterloo A *et al.* Perioperative mortality of elective abdominal aortic aneurysm surgery. *Arch Intern Med* 1995; **155**: 1998–2004.
23 Akkersdijk G, Vandergraaf Y, Moli F *et al.* Complication of standard elective abdominal aortic aneurysm repair. *Eur J Endovasc Vasc Surg* 1998; **15**: 505–510.
24 Diehl J, Cali R, Hertzer N, Beven E. Complications of abdominal aortic reconstruction. An analysis of perioperative risk factors in 557 patients. *Ann Surg* 1983; **197**: 49–56.
25 Leather R, Shah D, Kaufman J *et al.* Comparative analysis of retroperitoneal and transperitoneal aortic replacement for aneurysm. *Surg Gynecol Obstet* 1989; **168**: 387–393.
26 Hallet J, Naessens J, Ballard D. Early and late outcome of surgical repair for small abdominal aortic aneurysms: a population-based analysis. *J Vasc Surg* 1993; **18**: 684–691.
27 Becquemin JP, Mellière D, Desgranges P, Cavillon A, Allaire E. Anévrismes de l'aorte abdominale opérés: facteurs de risque et survie. *J Mal Vasc* 1995; **20**: 296–300.
28 L'AURC, Kieffer E, Koskas F, Dewailly J, Gouny P. Mortalité périopératoire de la chirurgie élective des anévrismes de l'aorte abdominale: étude multi-centrique de l'AURC. In: Kieffer E, ed. *Les Anévrismes de l'Aorte Abdominale Sous-rénale.* Paris: AERCV, 1990: 235–243.

Accepted 11 January 2000